Robotic Platform for an Interactive Tele-echographic System: The PROSIT ANR-2008 project

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INTRODUCTION

One of telemedicine's major applications is to provide skilled medical care to patients who are in some way isolated from the specialised care they need while maintaining high quality and controlled interactions with the distant experts. This is especially the case for patients living in isolated areas with reduced or substandard medical facilities. As ultrasound imaging is becoming more and more a part of emergency medical or surgical decision-making, there is a greater need for this technique to be accessible in a majority of the isolated areas lacking ultrasound specialists.
However, this specialised image investigation is an "expert-dependant" technique. Hence in the last decade, several robotized telemedicine concepts and scenarios have been investigated [1]. While this first generation of simple tele-echographic systems are now commercially made available by Robosoft (F), the potential market can only be addressed with more sophisticated interactive functionalities. This is the main goal of PROSIT ANR French national project [2], as these new interactive functionalities require scientific and technology breakthroughs.
PROSIT goal is to develop an interactive and complex master-slave robotic platform for a tele-echography diagnosis application. The development of this platform is based on the expertise of six partners: PRISME (Orleans University-coordinator), Robosoft, INRIA Rennes [3], LIRMM [4] (Montpellier II), PPRIMME [5] (Poitiers university) and INSERM930 [6] (UMPS-Tours University). In this paper, we will focus on the bilateral teleoperation issue and more specifically on the input device; it role is to provide the medical expert with a close rendering of the distal environment, that is the contact force between the ultrasound probe held by the robot end-effector and the patient's body.

MATERIALS AND METHODS

The PROSIT tele-echography platform is a teleoperation scheme composed of three main parts (fig. 1):

- The expert station: the medical expert receives the patient ultrasound images and uses a dedicated input device to control the orientations of the end-effector,
- The patient station: a robotic mobile emergency unit combined with an ultrasound device. A paramedical assistant maintains the probe holder robot on a chosen patient's anatomical area according to the expert's needs,
- The communication link that's provides a minimum 256kbps bandwidth (terrestrial, satellite…)

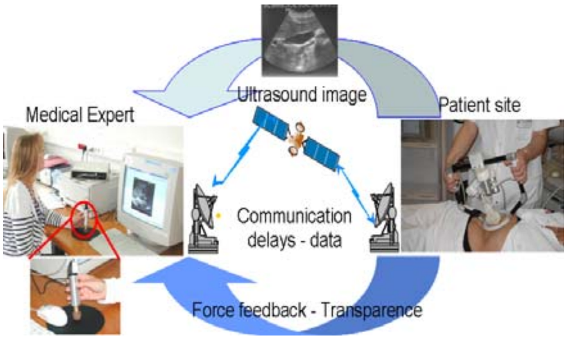

Fig. 1 Platform developed for PROSIT with a dedicated hand-free input device on the expert side, and probe holder maintained by the paramedical assistant on the patient side.

When the robot end-effector is equipped with a force sensor (Fig. 2), it provides the force information of the robot interaction with its environment that can be fed back to the operator via the communication network. The rendering of the distal environment properties (e.g. impedance of the patient's body) to the human operator is performed using a haptic input device. PROSIT challenge is to design a new bilateral teleoperated scheme based on a hand-free haptic device (fig.3). In order to provide the medical expert with the best transparency and robust solutions, one has to take into account the consequences of variable time-delays problems inherent to the Internet communication links. Several approaches are being currently tested within PROSIT Framework; one being developed by Fraisse [4] proposing a robust control force strategy by considering the upper boundaries of the environment stiffness and the static gain of the dynamic model. The other scheme under development is based on the network theory approach [7, 8] to maintain transparency and minimum steady state error in force and position using the passivity of the wave variables properties of [9,10].

Fig. 2: 4 DOF PROSIT-0 prototype, the prismatic z axis carries the ultrasound probe and maintains it in contact with the patient's skin and is based on the PRISME patent [10]

The development of theses schemes as well as of the haptic device is based on the users requirements defined by INSEM390 partner using developed robotic mechanical architecture [6].

RESULTS

The first PROSIT prototype has been built. It is a 4-DOF serial type robot with a remote centre of motion. This RCM corresponds to the contact of the ultrasound probe tip with the patient's skin. The prismatic z-axis enables to exert a maximum force of about 20N on the patient's body. One of the main characteristics is that it can hold any type of ultrasound probes used in the medical radiology department; it is under technical and clinical tests with Tours university hospital. This prototype is teleoperated via any communication links and using a passive input device with a flock of bird (FOB) position sensor from ascension technology. However, to satisfy the users requirements and improve the system transparency, a new hand-free haptic device for PROSIT has been designed; it has a similar appearance as of a standard ultrasound probe; it is a light and easily transportable, active haptic system.

Fig. 3: Haptic probe CAD providing the environment impedance variations to the operator

It integrates inertial sensors and an accelerometer in order to obtain angular and displacement variations in order to register the expert's hand movements; these sensors are an alternative to the FOB system as they are not sensitive to electromagnetic fields. This ergonomic haptic probe integrates a force sensor and an actuator to provide, a good rendering of the environment impedance variations during the tele-echography act. The position accuracies have been assessed using the Vicon Nexus motion capture system. A force sensor at the slave system provides the force applied by the ultrasound sensor on the patient's skin and sends the information in real time to the master site.

DISCUSSION

On the clinical aspect, the tele-echography robotised system performance is evaluated by comparing it to a conventional echography done on the same patient. The medical team evaluates a score expressed as a percentage of the number of patients for whom the organs could be visualised using the robot with respect to the number of patients for whom all organs could be visualised using conventional echography. With this prototype, 87% of abdominal robotic echographies were successful in visualising all the set of organs needed to provide a reliable diagnosis. These preliminary results show the need of such a system in comparable emergency situations. In order to improve these results, visual servoing will be added to the system to track a region of interest of the ultrasound image to compensate for mechanical defaults or data loss in the communication link.

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